Localized Corrosion in Aluminum Alloys by the Scanning Reference Electrode Technique

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Corrosion of aluminum alloys is generally measured on a macroscopic scale using a relatively large surface area of a test specimen and measuring the corrosion currents. However, the corrosion generally is not uniform on a microscopic scale. Work with aluminum-lithium alloys indicates that they are susceptible to pitting corrosion,[1] a localized corrosion phenomenon. Recently, MSFC has employed the Scanning Reference Electrode Technique for measuring such localized corrosion.

The Scanning Reference Electrode Technique instrument (fig. 101) is commercially available, has the capability to measure microgalvanic potentials close to the surface of materials, and allows in-situ examination and quantification (on a microscopic scale) of electrochemical activity as it occurs. The tool is microprocessor-controlled, and electrical potentials are measured by a special probe capable of translation in the X and Y directions. The specimen, in the form of a cylinder, is held in a vertical position and rotated around the Y-axis. The scan is synchronized with a display monitor, and the resultant data are shown in the form of line scans or two-dimensional area maps. The width of the area maps (X direction) can be set at will using the zoom-in feature of the experimental setup. The height of the area maps (Y direction) is set automatically by the control software according to the proper aspect ratio. Movement of the scanning probe during data collection is in the Y direction. Direct measurement of surface potentials, showing anodic and cathodic areas, at discrete positions on the sample surface may be taken and stored for time-related studies. Because the minimum detectable signal is on the order of 1 milliamp per square centimeter, a potential must be applied to the sample to increase the corrosion current to at least this level. This is accomplished by means of a separate potentiostat coupled to the Scanning Reference Electrode Technique system.

FIGURE 101.—The Scanning Reference Electrode Technique.

Corrosion testing specimens consisted of cylindrical metal rods approximately 1.27 centimeters (0.5 inch) in diameter and 10.2 centimeters (4 inches) in length. In the case of welded samples, a longitudinal V-groove was machined along the entire length of the rod (Y direction). The groove was then filled using 4043 filler by tungsten inert-gas welding and subsequently machined down to a smooth circular surface. Samples were immersed in a corrosive medium consisting of 3.5-percent sodium-chloride solution. A potential was then applied to each sample, as the sample was rotated at 100 revolutions per minute during the scan. The experiments were set up in such a way that all maps had a width of 3.0 centimeters (X direction) and a height of 2.25 centimeters (Y direction). After data collection, each map was displayed on the computer screen and the proper palette for the display of map features was selected. Topography measurements of the various map features (potentials for anodic and cathodic regions) were then made. All cathodic features have positive signs, while all anodic features are negative.

Area map scans for the wrought 2195 aluminum-lithium alloy (fig. 102) and the welded material (4043 filler) (fig. 103) were recently made. The scales of both maps are expanded by a factor of approximately four over those actually occurring in the samples. The map scan for the wrought material (fig. 102) shows many strongly anodic and cathodic features, indicating a strong tendency toward pitting for this material. In contrast, the map scan for the welded material (fig. 103) is highly striated in the direction of the weld. The area containing the weld is entirely cathodic and extends slightly into the heat-affected zone. Strong anodic regions border the weld on both sides, indicating a high propensity for corrosion in these areas.

From these results, it is clear that the Scanning Reference Electrode Technique provides an excellent means for studying localized corrosion on a microscopic scale, showing a marked change in the corrosion characteristics brought about through the welding of materials. Such information is not available from conventional corrosion measurements, through which only overall corrosion rates can be obtained. Soon, however, it will be possible to correlate the overall corrosion rate measurements with the localized corrosion measurements provided by this new technique, delivering an even greater understanding for the corrosion behavior of various materials.

[1]Walsh, D.W. August 1994. NASA/American Society for Engineering Education Summer Faculty Fellow.

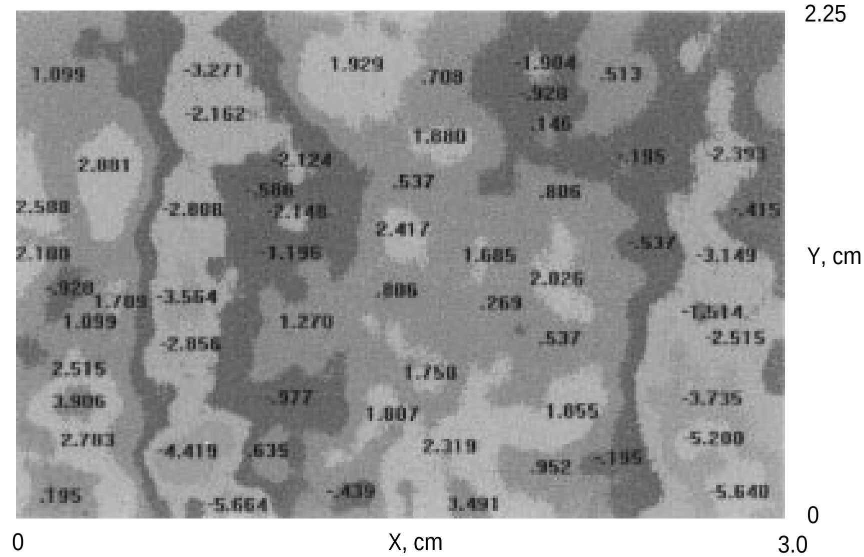

FIGURE 102.—Localized corrosion in wrought 2195 aluminum-lithium alloy.

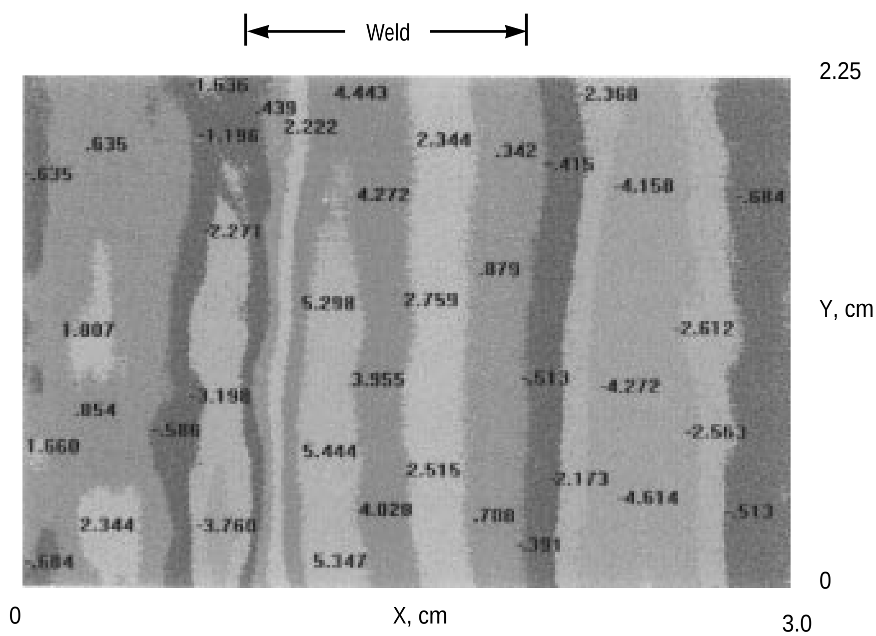

FIGURE 103.—Localized corrosion in welded 2195 aluminum-lithium alloy (4043 filler).

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